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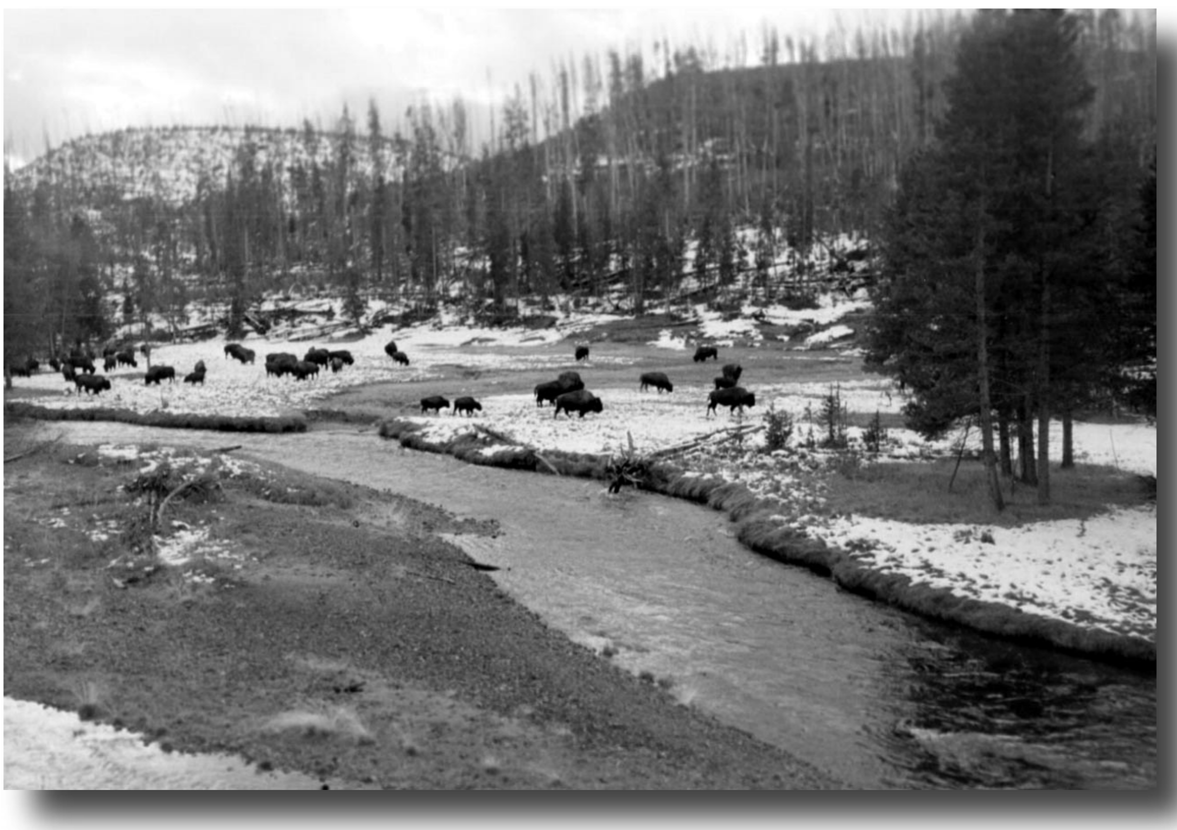
Suspended-Sediment Concentration and Pool Sedimentation Data for the Gibbon River, Yellowstone National Park, Wyoming, September 2000 through October 2001

Open-File Report 03-185



Prepared in cooperation with the

NATIONAL PARK SERVICE

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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By Peter R. Wright and Ronald B. Zelt

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Cheyenne, Wyoming
2003

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CONVERSION FACTORS, DATUMS AND ABBREVIATIONS

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
inch (in)	2.54	centimeter (cm)
inch (in)	25.40	millimeter (mm)
mile (mile)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Load	
ton per day (ton/d)	907.2	kilogram per day

Temperature can be converted to degrees Fahrenheit (^oF) or degrees Celcius (^oC) as follows:

$$^oF = 9/5\,(^oC) + 32$$
$$^oC = 5/9\,(^oF - 32)$$

In this report, vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929); horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Abbreviations used in this report:

cm	centimeter
ft^3/s	cubic foot per second
GCLAS	Graphical constituent loading analysis system
m	meter
m^2	square meter
m^3	cubic meter
m^3/s	cubic meter per second
mg/L	milligrams per liter
mm	millimeter
µm	micrometer
USGS	U.S. Geological Survey
YNP	Yellowstone National Park

Suspended-Sediment Concentration and Pool Sedimentation Data for the Gibbon River, Yellowstone National Park, Wyoming, September 2000 through October 2001

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ABSTRACT

This report presents data on streamflow, suspended-sediment concentration, geomorphic measurements of pools, and particle-size distribution of surficial bed material, collected along a 5-mile reach of the Gibbon River in Yellowstone National Park. The study was done in cooperation with the National Park Service. The Park Service was concerned about the potential effects that road reconstruction would have on water quality.

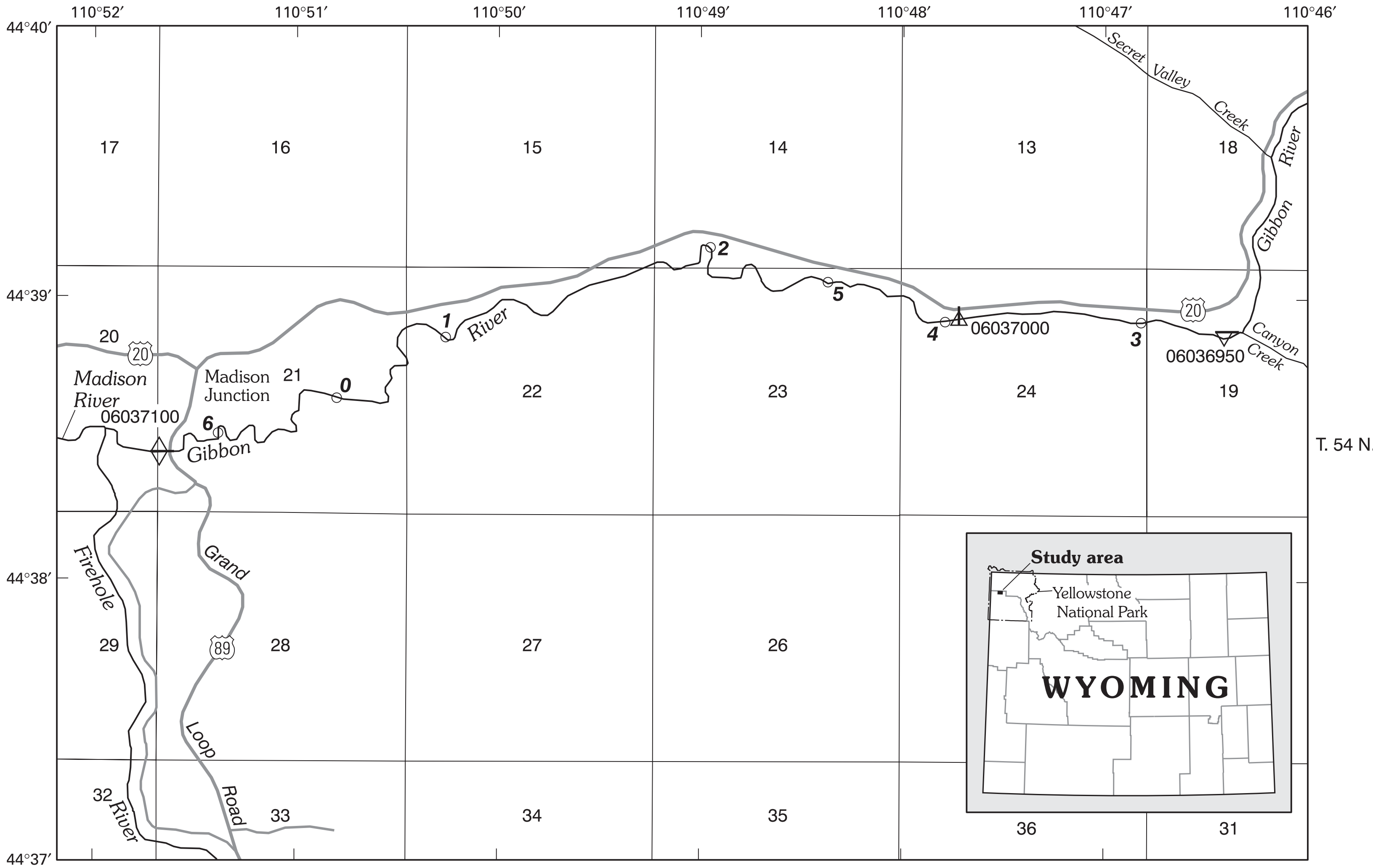
A streamflow-gaging station and two automatic pumping samplers were installed in September 2000 to collect suspended-sediment samples. The gage and samplers were operated seasonally from March through September 2001. The geomorphic survey of pools and sampling of bed material occurred during October 2000.

INTRODUCTION

The Gibbon River in Yellowstone National Park (YNP) (fig. 1) is an important trout fishery, featuring geothermally affected water in which fish and invertebrates are buffered against extremely low temperatures and ice formations (Varley and Schullery, 1983). In 1997, the Gibbon River ranked sixth in popularity among 73 streams and lakes fished in YNP (National Park Service, 1999). Several events in the Gibbon watershed since 1988 have individual or cumulative potential to increase sediment yields. The Gibbon River drainage was severely burned in the Greater Yellowstone fires of 1988 (Greater Yellowstone Coordinating Committee, 1989). Subsequent rain runoff produced debris flows that deposited large volumes of sediment and rock along and within the channel of the Gibbon River during 1989-91 (Meyer, 1993). Lastly, reconstruction and partial re-routing of the paved Park Service road along the Gibbon River commenced in the spring of 2001, which could represent a source of potential sediment erosion. Road reconstruction is planned to be completed in several phases over the following 4 to 6 years (National Park Service, 1999).

Deposition of fine sediment on the streambed can cause decreased survival of salmonid eggs and alevins by restricting flow and dissolved-oxygen distribution through streambed gravel, resulting in suffocation. Filling of pools with fine sediment deposits can reduce available habitat for benthic invertebrate communities that live on the surfaces of coarse substrate. Sediment-caused turbidity decreases light penetration, which may inhibit primary production and disrupt food-chain energy transfer. Finally, increased turbidity adversely affects aesthetic values of streams, an important consideration for high-profile streams such as those in YNP.

Concerns about the potential effects that road reconstruction would have on water quality prompted the National Park Service and the U.S. Geological Survey (USGS) to enter into an agreement to characterize sediment conditions in the Gibbon River. The study was designed to: (1) document the mean daily suspended-sediment concentrations, fine bed-sediment size distribution in pools, and degree of pool sedimentation of the Gibbon River prior to the road reconstruction activity, (2) monitor conditions during the reconstruction period, and (3) compare the post-construction conditions with the pre-construction baseline to evaluate any substantial changes.



Base modified from University of Wyoming, Spatial Data and Visualization Center digital data, 1996
Lambert Conformal Conic projection, Standard parallels 44° and 45°, central meridian 111°00′

EXPLANATION

06037100 Streamflow-gaging station and sediment-measurement site and number

06037000 Inactive streamflow-gaging station and number

06036950 Sediment-measurement site and number

6 Pool study reach and number

Figure 1. Location of streamflow-gaging stations, sediment-measurement sites, and pool study reach points along the Gibbon River, Yellowstone National Park, Wyoming.

Purpose and Scope

The purpose of this report is to present the data collected during the first two seasons of this study (September 2000 through October 2001). Streamflow and suspended-sediment data are published here and as part of the Wyoming Water Resources Data Report for the 2001 water year (Swanson and others, 2002). Other data in this report include the geomorphic survey data for 16 pools, along with particle-size data for 18 samples of fine bed-sediment in pools. Methods of data collection and quality-assurance data are included in this report.

Description of Area

The Gibbon River originates at Grebe Lake at an elevation of 8023 ft (feet) above NGVD of 1929 and flows 29 miles southwesterly to join the Firehole River at an elevation of 6798 ft. The upper river drains a high, mountainous area with small tributaries fed by snowmelt and cold springs. Middle reaches of the river receive tributary flows fed by snowmelt and cold springs (such as Solfatara Creek, Canyon Creek, and Secret Valley Creek), and effluent from geyser basins (Norris, Gibbon, and Monument) and hot springs (such as Sylvan, Beryl, and Iron). Soils are sandy, originating chiefly from glacial till or colluvium (National Park Service, 1999). Streambed materials are primarily volcanic rhyolite, with gravel constituting the largest size fraction (Vincent, 1967).

The snowmelt runoff period typically begins in mid-April, peaks by mid-June, and then declines rapidly until mid-July. During the remainder of the year, flows generally are low and relatively constant, although heavy rains and ensuing runoff events are not uncommon. The geyser and hot spring effluent contribute about 2 percent of total flow of the river during the snowmelt runoff period, and about 6 percent during low-flow conditions (Vincent, 1967). During the period from March 23, 2001 to October 11, 2001, the Gibbon River at Grand Loop Road Bridge had a maximum daily mean flow of 584 ft^3/s (cubic feet per second) on May 16 and a minimum daily mean flow of 79 ft^3/s on September 4. Daily mean sediment loads during this same period reached a maximum daily load of 596 tons/d (tons per day) on May 16 and a minimum daily load of 0.77 tons/d on June 27.

METHODS

The studied segment of the Gibbon River was based upon the area of road reconstruction. The study segment extends from the Gibbon Falls picnic area downstream to the Grand Loop Road Bridge at Madison Junction—a distance of about 5 mi. At the upper end of the study segment, which starts just below the mouth of Canyon Creek, a portable automatic water-quality sampler was installed. At the lower end of the study segment, a streamflow-gaging station and a portable automatic water-quality sampler were installed on the downstream side of the Grand Loop Road Bridge at Madison Junction (station 06037100). Within the study segment, 7 reaches were delineated for geomorphic pool surveys and 16 individual pool areas were identified for data collection.

Streamflow

Streamflow-gaging station 06037100 was installed in September 2000 and activated on March 20, 2001. It was operated until it was closed down for the cold-weather season on October 11, 2001. Levels were surveyed to establish a datum for which relative gage heights could be reported. Streamflow was measured periodically to establish a stage-flow rating, and daily mean streamflow records were computed in accordance with standard USGS methods (Rantz and others, 1982). Daily streamflow records for the seasonal period of gage operation are presented in table 1 at the back of this report. Streamflow measurements are listed in table 2 at the back of this report.

Suspended Sediment

Two automatic pumping samplers were installed in the Gibbon River in September 2000. Each of these samplers, one just below the inflow of Canyon Creek (station 06036950) and the other at Madison Junction (station 06037100), were used to collect water samples that were analyzed for suspended-sediment concentration. The sampler immediately below the confluence of Canyon Creek was installed to attempt to detect possible effects of sediment inputs from debris torrents or erosion of debris fans that are not associated with road reconstruction.

Both automatic samplers were operated using the same sampling frequency. The samplers were programmed to collect once-daily samples from March 22 through June 28, 2001. A subset of these samples representing every other day from April 13 through May 5, 2001 was sent for analysis. Samples for May 6 through May 13, 2001 were lost in transit. All daily samples for May 14 through June 28, 2001 were sent for analysis.

After the snowmelt runoff period had ended in June, the samplers were reprogrammed to collect storm runoff "event" samples. An "event" was defined as any flow magnitude within the upper 10 percent of the flow-duration curve. The Gibbon River did not have any events large enough to reach the upper 10 percent of the duration curve so no "event" samples were collected.

Automatic samplers are efficient tools for the collection of water samples in remote areas or during short-duration events. However, these samples do not represent the "true" mean suspended-sediment concentration of the stream at the time of collection, because the sample is pumped from a single point in the cross section (Edwards and Glysson, 1999). To determine the "true" mean, a relation needs to be determined by comparing automatic point samples with depth-integrated, cross-sectional samples over the full range of flow (Edwards and Glysson, 1999). Depth-integrated, equal-width increment, cross-sectional samples (table 2) were collected concurrently with corresponding automatic point samples. Cross-sectional samples were collected in accordance with standard USGS protocols described by Edwards and Glysson (1999). These protocols are designed to provide discharge-weighted composite samples that best represent the mean suspended-sediment concentration across the entire cross section.

All samples submitted to the laboratory were analyzed for suspended-sediment concentration, and approximately 30 percent of those samples were analyzed for sand-silt distribution (percent less than 0.062-mm (millimter) diameter). Suspended-sediment concentration and particle-size distribution data for point samples collected at station 06036950 are presented in table 3, and for station 06037100 are presented in table 4. Samples were analyzed by the USGS sediment laboratory in Helena, Montana, in accordance with methods described in Guy (1969) and Lambing and Dodge (1993).

To determine the daily suspended-sediment load (suspended-sediment mass discharged over a 24-hour period), daily suspended-sediment concentrations from automatic samples and streamflow data were utilized with data from depth-integrated cross-sectional samples using the computer program "Graphical Constituent Loading Analysis System" (GCLAS) of the USGS (McKallip and others, 2001). Mean-daily suspended-sediment concentration and load data, calculated using GCLAS, are presented in table 5 for station 06037100.

Geomorphology of Pools

Seven reaches of the Gibbon River distributed about evenly along the study segment between sediment-measurement sites (fig. 1) were selected for targeted geomorphic sampling. These reaches provided a suitable set of pools for monitoring fine-sediment deposition during low flow. The study reaches have gradients and pool spacing typical of pool-riffle or plane-bed channel types (Montgomery and Buffington, 1993). For the purposes of this study, pools were defined at low flow as areas of the channel with reduced velocity, little surface turbulence, deeper water than surrounding areas (Fitzpatrick and others, 1998), a distinct downstream terminus ("riffle crest"), and containing the channel thalweg (Lisle and Hilton, 1992). The residual pool is defined as the portion of the pool that is deeper than the hydraulic control (riffle crest) at the downstream end of the pool. In other words, the residual pool is the portion of the pool that would remain filled with water when the stream is barely flowing.

Within these 7 reaches, a total of 16 pools were measured and sampled in October 2000 using methods described by Hilton and Lisle (1993). Data were collected and used to determine the proportion of residual pool volume filled by fine sediment (Lisle and Hilton, 1992, 1999) during low flow. The fraction of residual pool volume filled with fine sediment (V_*) is the ratio of fine-sediment volume (V_{rf}) to the combined pool water and fine-sediment volume (V_r) (Lisle and Hilton, 1992, 1999).

The calculation of V_* requires measurements of the water and fine-sediment volumes within the "residual" part of each pool. The first step in measuring each pool was to measure the riffle-crest depth. This was measured as the mean of several soundings in the thal-

weg at the downstream terminus of each pool. The riffle crest depth was then used to physically determine the residual pool boundaries. For example, if a pool had a riffle crest depth of 10 cm (centimeters) then the residual pool boundary would be all areas of the pool that have a combined water/fine-sediment depth of 10 cm or greater.

Reach length and position of each pool relative to a reference station (reach point 0) were measured approximately along the stream centerline. Eleven to 25 soundings were made along a minimum of four transects across each pool, using a graduated steel rod 0.95 cm (0.375 in. (inch)) in diameter. Abrupt changes in resistance to penetration of the rod as it passed from sand or fine gravel to packed coarse gravel and cobbles indicated the base of the fine-sediment deposit.

Table 6 lists the results of the various geomorphic measurements of the 16 pools in the study segment. On the basis of these measurements, the volume-weighted mean proportion (V_{*w}) of the residual pool volumes filled with fine sediment was 14.9 percent.

From each of the measured pools, bed-material samples of the fine sediment overlying the gravel framework were collected. These samples were analyzed by Inberg-Miller Engineers in Cheyenne, Wyoming, to determine the size distribution of the fine bed sediments filling each pool. The results of these analyses are listed in table 7.

Samples of the fine bed sediments were collected using a 52-mm (2-in.) diameter pipe dredge with an attached sampling bag. The dredge sampler was used to collect a bulk composite sample of the residual pool fines from a minimum of three different sampling points in each pool. Two replicate samples of bed material were collected and analyzed for quality control.

Surficial bed material was sampled in one riffle as part of this study. This was accomplished using a pebble count (Wolman, 1954) of at least 100 particles along a tape or transverse line using $d_{\max}$ spacing (that is, the largest clast expected along the transect; see Bunte and Abt, 2001, p. 146-147). The intermediate-diameter size class of each clast was measured using a US SA-97 hand-held particle-size analyzer (template). The particle-size distribution of the sampled riffle is listed in table 8. The degree to which sampled particles larger than 6 mm were embedded in fine sediment was visually estimated for one-half of those sampled particles (every second particle selected). Embeddedness data also are listed in table 8.

REFERENCES

Bunte, K. [I.], and Abt, S.R., 2001, Sampling surface and subsurface particle-size distributions in wadable gravel- and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring: U.S. Department of Agriculture, Forest Service General Technical Report RMRS-GTR-74, 428 p.

Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2, 89 p.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and Gurtz, M.E., 1998, Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 98-4052, 67 p.

Greater Yellowstone Coordinating Committee, 1989, The Greater Yellowstone postfire assessment: Greater Yellowstone Coordinating Committee, Postfire Assessment Committee, 147 p.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1, 58 p.

Hilton, Sue, and Lisle, T.E., 1993, Measuring the fraction of pool volume filled with fine sediment: Albany, Calif., U.S. Forest Service Pacific Southwest Research Station Research Note PSW-RN-414, 11 p.

Lambing, J.H., and Dodge, K.A., 1993, Quality assurance for laboratory analysis of suspended-sediment samples by the U.S. Geological Survey in Montana: U.S. Geological Survey Open-File Report 93-131, 34 p.

Lisle, T.E., and Hilton, Sue, 1992, The volume of fine sediment in pools—An index of sediment supply in gravel-bed streams: Water Resources Bulletin, v. 28, no. 2, p. 371-383.

______1999, Fine bed material in pools of natural gravel bed channels: Water Resources Research, v. 35, p. 1291-1304.

McKallip, T.E., Koltun, G.F., Gray, J.R., and Glysson, G.D., 2001, GCLAS - A Graphical Constituent Loading Analysis System, *in* Proceedings of the Seventh Federal Interagency Sedimentation Conference, Reno, Nevada, March 25-29: Subcommittee on Sedimentation, v. II, p. VI-49 to VI-52.

Meyer, G.A., 1993, Holocene and modern geomorphic response to forest fires and climate change in Yellowstone National Park: Albuquerque, University of New Mexico, unpublished Ph.D. dissertation, 402 p.

Montgomery, D.R., and Buffington, J.M., 1993, Channel classification, prediction of channel response, and assessment of channel condition: Washington State Timber/Fish/Wildlife Agreement, Report TFW-SH10-93-002, 84 p.

National Park Service, 1999, Environmental assessment—Madison Junction/Norris Junction road improvement, Yellowstone National Park: Denver, Colo., National Park Service, 84 p.

Rantz, S.E., and others, 1982, Computation of discharge: U.S. Geological Survey Water-Supply Paper 2175, 2 v., 631 p.

Swanson, R.B., Woodruff, R.E., Laidlaw, G.A., Watson, K.R., and Clark, M.L., 2002, Water resources data, Wyoming, water year 2001; Volume 1. Surface water: U.S. Geological Survey Water-Data Report WY-01-1, 518 p. Online (downloadable pdf file) at *http://wy.water.usgs.gov/pubs/adr/index.htm#Water Year 2001*.

Varley, J.D., and Schullery, P., 1983, Freshwater wilderness, Yellowstone fishes and their world: Yellowstone Library and Museum Association, Yellowstone National Park, 132 p.

Vincent, E.R., 1967, A comparison of riffle insect populations in the Gibbon River above and below the geyser basins, Yellowstone National Park: Limnology and Oceanography, v. 12, p. 18-26.

Wolman, M.G., 1954, A method of sampling coarse river bed material: AmericanGeophysical Union Trnsactions, v. 35, no. 6, p. 951-956.

DATA TABLES

Table 1. *Daily mean streamflow data for station 06037100, Gibbon River at Grand Loop Road Bridge at Madison Junction, Yellowstone National Park, Wyoming, March 23 through September 30, 2001*

[MAX, maximum; MIN, minimum; AC-FT, acre-feet; --, no data]

LOCATION.--Latitude 44°38'26", longitude 110°51'40", Teton County, Hydrologic Unit 10020007, Yellowstone National Park, on right bank, downstream side of bridge on highway 191-287, 0.2 miles upstream from the confluence with the Firehole River, 0.3 miles south of Madison Junction, and 14 miles east of West Yellowstone, Mont.

DRAINAGE AREA.--126 square miles.

GAGE.--Water-stage recorder. Elevation of gage is 6,800 ft above NGVD of 1929, from topographic map.

REMARKS.--Records fair. No regulation or diversions upstream from station. Streamflow measurement made on Oct. 12 during period station was not in operation was 138 cubic feet per second.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 2000 TO SEPTEMBER 2001
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	--	--	--	--	--	--	103	261	159	112	93	84
2	--	--	--	--	--	--	107	213	153	109	90	82
3	--	--	--	--	--	--	103	189	154	108	88	81
4	--	--	--	--	--	--	104	189	160	108	90	79
5	--	--	--	--	--	--	103	210	155	111	89	84
6	--	--	--	--	--	--	105	220	160	110	86	87
7	--	--	--	--	--	--	105	210	148	111	87	86
8	--	--	--	--	--	--	109	225	143	117	88	85
9	--	--	--	--	--	--	102	260	139	122	88	82
10	--	--	--	--	--	--	100	257	133	139	87	81
11	--	--	--	--	--	--	98	249	128	124	87	80
12	--	--	--	--	--	--	100	254	141	118	87	81
13	--	--	--	--	--	--	101	264	153	113	88	84
14	--	--	--	--	--	--	99	262	166	114	95	86
15	--	--	--	--	--	--	92	326	182	118	97	86
16	--	--	--	--	--	--	94	584	145	121	92	85
17	--	--	--	--	--	--	101	425	131	114	92	86
18	--	--	--	--	--	--	121	323	129	109	90	84
19	--	--	--	--	--	--	143	276	127	107	88	84
20	--	--	--	--	--	--	142	248	125	105	87	83
21	--	--	--	--	--	--	140	228	122	103	88	81
22	--	--	--	--	--	--	131	214	120	102	88	81
23	--	--	--	--	--	99	127	202	119	101	87	81
24	--	--	--	--	--	102	125	190	117	99	85	80
25	--	--	--	--	--	104	144	183	116	98	85	80
26	--	--	--	--	--	103	165	190	116	97	84	81
27	--	--	--	--	--	102	201	180	116	96	83	81
28	--	--	--	--	--	103	227	201	114	96	83	81
29	--	--	--	--	--	104	259	236	114	94	83	82
30	--	--	--	--	--	106	235	179	113	95	82	81
31	--	--	--	--	--	99	--	165	--	93	83	--
TOTAL	--	--	--	--	--	922	3,886	7,613	4,098	3,364	2,720	2,479
MEAN	--	--	--	--	--	102	130	246	137	109	87.7	82.6
MAX	--	--	--	--	--	106	259	584	182	139	97	87
MIN	--	--	--	--	--	99	92	165	113	93	82	79
AC-FT	--	--	--	--	--	1,830	7,710	15,100	8,130	6,670	5,400	4,920

Table 2. *Streamflow measurements and width- and depth-integrated suspended-sediment data for the Gibbon River, September 14, 2000 through October 11, 2001*

[ft, feet; ft^3/sec, cubic feet per second; Conc., suspended-sediment concentration; mg/L, milligrams per liter; mm, millimeter; --, no data]

Date	Time	Streamflow, instantaneous (ft^3/sec)	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Gage height (ft)	Streamflow, instantaneous (ft^3/sec)	Conc. (mg/L)	Percent finer than 0.062 mm
	06036950 - Gibbon River below Canyon Creek near West Yellowstone, Montana				06037100 - Gibbon River at Grand Loop Road at Bridge Madison Junction, Yellowstone National Park, Wyoming				
09-14-00	1225	85	5	--	1445	4.09	105	4	--
09-27-00	1600	85	9	90	1700	4.10	100	21	54
10-12-00	--	--	--	--	1030	4.18	138	6, [1]5	--
10-15-00	1500	96	3, [1]3	--	--	--	--	--	--
03-22-01	1730	89	10	--	1500	4.06	107	10	--
05-14-01	2002	--	16	83	1602	4.69	274	28	77
05-14-01	2004	--	17	79	1604	4.69	274	21	80
05-14-01	2006	--	17	79	1606	4.69	274	30	50
05-18-01	1002	324	23	67	0902	4.95	331	33	80
05-18-01	1004	324	19	72	0904	4.95	331	23	75
05-18-01	1006	324	21	70	0906	4.95	331	30	51
06-05-01	1302	154	5	93	1102	4.28	149	6	87
06-05-01	1304	154	5	85	1104	4.28	149	6	88
06-05-01	1306	154	4	62	1106	4.28	149	5	78
06-28-01	1600	94	--	--	1400	4.11	110	--	--
08-13-01	--	--	--	--	1530	4.01	86	--	--
10-11-01	1301	69	26	57	1001	4.00	88	12	58
10-11-01	1302	69	4	--	1002	4.00	88	2	--
10-11-01	[2]1303	--	--	--	1003	4.00	88	2	80
10-11-01	1304	69	4	--	1004	4.00	88	2	--
10-11-01	[2]1305	--	--	--	1005	4.00	88	--	78
10-11-01	1306	69	5	--	1006	4.00	88	--	--
10-11-01	1307	69	2	91	1007	4.00	88	--	78

[1]Replicate sample.
[2]Samples lost in transit.

Table 3. *Suspended-sediment data for automatic-pumped samples collected at station 06036950, Gibbon River below Canyon Creek, near West Yellowstone, Montana, March 22 through June 28, 2001*

[These data represent suspended-sediment concentrations of instantaneous point samples collected using an automatic pumping sampler. Conc., concentration; mg/L, milligrams per liter; mm, millimeter; --, no data]

Day	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm
	March			April			May			June		
1	--	--	--	1900	11	--	1900	126	--	1200	28	--
2	--	--	--	--	--	--		--	--	1200	19	85
3	--	--	--	1900	14	--	1900	141	--	1200	32	--
4	--	--	--	--	--	--		--	--	1200	18	--
5	--	--	--	1900	13	70	1900	36	75	1200	14	48
6	--	--	--	--	--	--	--	--	--	1200	11	--
7	--	--	--	1900	9	--	--	--	--	1200	11	81
8	--	--	--	--	--	--	--	--	--	1200	14	--
9	--	--	--	1900	13	--	--	--	--	1200	11	--
10	--	--	--	--	--	--	--	--	--	1200	13	72
11	--	--	--	1900	13	80	--	--	--	1200	15	--
12	--	--	--	--	--	--	--	--	--	1200	13	--
13	--	--	--	1900	18	--	--	--	--	1200	7	91
14	--	--	--	--	--	--	2000	1922	--	1200	19	--
15	--	--	--	1900	17	--	2000	1115	5	1200	31	--
16	--	--	--	--	--		2000	733	--	1200	13	82
17	--	--	--	1900	66	87	2000	183	--	1200	11	--
18	--	--	--	--	--	--	2000	60	--	1200	9	--
19	--	--	--	1900	27	--	1200	38	--	1200	10	70
20	--	--	--	--	--	--	1200	38	--	1200	12	--
21	--	--	--	1900	29	--	1200	25	70	1200	12	--
22	1900	11	--	--	--	--	1200	37	--	1200	10	75
23	--	--	--	1900	29	86	1200	35	--	1200	12	--
24	1900	13	79	--	--	--	1200	23	70	1200	13	--
25	--	--	--	1900	102	--	1200	25	--	1200	13	55
26	1900	13	--	--	--	--	1200	26	--	1200	9	--
27	--	--	--	1900	201	--	1200	24	62	1200	17	--
28	1900	13	--	--	--	--	1200	50	--	1200	17	40
29	--	--	--	1900	117	67	1200	76	--	--	--	--
30	1900	12	88	--	--	--	1200	28	64	--	--	--
31	--	--	--	--	--	--	1200	26	--	--	--	--

Table 4. *Suspended-sediment data for automatic-pumped samples collected at station 06037100, Gibbon River at Grand Loop Road Bridge at Madison Junction, Yellowstone National Park, Wyoming, April 7 through June 28, 2001*

[These data represent suspended-sediment concentrations of instantaneous point samples collected using an automatic pumping sampler. Conc., concentration; mg/L, milligrams per liter; mm, millimeter; --, no data]

Day	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm	Time	Conc. (mg/L)	Percent finer than 0.062 mm
	March			**April**			**May**			**June**		
1	--	--	--	--	--	--	1900	37	--	1200	17	42
2	--	--	--	--	--	--		--	--	1200	18	--
3	--	--	--	--	--	--	1900	20	--	1200	17	--
4	--	--	--	--	--	--		--	--	1200	14	49
5	--	--	--	--	--	--	1900	23	82	--	--	--
6	--	--	--	--	--	--	--	--	--	1200	11	--
7	--	--	--	1900	22	--	--	--	--	1200	14	51
8	--	--	--	--	--	--	--	--	--	1200	11	--
9	--	--	--	--	--	--	--	--	--	1200	21	--
10	--	--	--	--	--	--	--	--	--	1200	7	90
11	--	--	--	--	--	--	--	--	--	1200	10	--
12	--	--	--	--	--	--	--	--	--	1200	9	--
13	--	--	--	1900	14	--	--	--	--	1200	9	81
14	--	--	--	--	--	--	1900	21	--	1200	12	--
15	--	--	--	1900	10	62	1900	83	81	1200	23	--
16	--	--	--	--	--		1900	1359	--	1200	11	88
17	--	--	--	--	--	--	1900	3510	--	1200	10	--
18	--	--	--	--	--	--	1200	141	--	1200	8	--
19	--	--	--	1900	18	--	1200	53	--	1200	6	96
20	--	--	--	--	--	--	1200	34	48	1200	15	--
21	--	--	--	1900	19	--	1200	34	--	1200	8	--
22	--	--	--	--	--	--	1200	27	--	1200	6	72
23	--	--	--	1900	18	84	1200	71	21	1200	12	--
24	--	--	--	--	--	--	1200	26	--	1200	8	--
25	--	--	--	1900	29	--	1200	26	--	1200	9	68
26	--	--	--	--	--	--	1200	21	59	1200	6	--
27	--	--	--	1900	49	--	1200	18	--	1200	4	--
28	--	--	--	--	--	--	1200	33	--	1200	10	46
29	--	--	--	1900	34	85	1200	43	71	--	--	--
30	--	--	--	--	--	--	1200	21	--	--	--	--
31	--	--	--	--	--	--	1200	13	--	--	--	--

Table 5. *Daily mean suspended-sediment concentrations and loads for station 06037100, Gibbon River at Grand Loop Road Bridge at Madison Junction, Yellowstone National Park, Wyoming, April 1 through June 30, 2001*

[mg/L, milligrams per liter; tons/d, tons per day; e, estimated, --, no data]

EXTREMES FOR PERIOD OF RECORD.--

SEDIMENT CONCENTRATION: Maximum daily mean during period of operation, 360 mg/L, May 16; minimum daily mean during period of operation, 2 mg/L, June 27.

SEDIMENT LOADS: Maximum daily mean during period of operation, 596 tons/d, May 16; minimum daily mean during period of operation, 0.77 ton/d, June 27.

Day	Mean concentration (mg/L)	Load (tons/day)	Mean concentration (mg/L)	Load (tons/day)	Mean concentration (mg/L)	Load (tons/day)
	April		**May**		**June**	
1	e12	e3.3	41	29	8	3.4
2	e14	e4.0	e35	e20	9	3.6
3	e16	e4.5	26	13	8	3.4
4	e18	e5.1	e36	e18	7	2.9
5	e20	e5.6	32	18	5	2.2
6	e22	e6.3	e32	e19	5	2.3
7	24	6.9	e38	e22	6	2.6
8	e24	e7.0	e41	e25	6	2.4
9	e22	e6.1	e50	e35	9	3.3
10	e21	e5.6	e52	e36	4	1.6
11	e19	e5.1	e36	e24	5	1.6
12	e18	e4.8	e24	e17	5	2.0
13	16	4.4	e21	e15	7	2.8
14	e14	e3.8	24	17	9	4.3
15	12	3.0	20	18	11	5.4
16	e13	e3.3	360	596	6	2.3
17	e15	e4.1	269	304	5	1.7
18	e17	e5.7	50	45	4	1.4
19	20	7.6	13	9.4	4	1.2
20	e21	e8.0	10	6.8	6	2.1
21	21	8.0	11	6.7	4	1.4
22	e21	e7.5	12	7.0	3	1.1
23	21	7.1	23	13	5	1.7
24	e25	e8.3	13	6.7	4	1.3
25	31	12	11	5.4	4	1.3
26	e41	e18	9	4.6	3	.94
27	52	28	9	4.3	2	.77
28	e49	e30	13	6.9	5	1.5
29	41	29	13	8.1	e6	e1.3
30	e40	e25	9	4.6	e6	e1.3
31	--	--	7	3.0	--	--
TOTAL	--	277.1	--	1,357.5	--	65.11

Table 6. *Summary of pool geometry measurements in the Gibbon River, October 2000*

[V_{rf}, volume of fine sediment in residual pool; V_*, fraction of residual pool occupied by fine sediment; Max, maximum; D_r, residual pool depth; D_{rc}, depth of riffle crest; V_r, volume of residual pool (water plus sediment); m^3, cubic meter; W_r, surface width of residual pool; m^2, square meters; cm, centimeters; Std. Dev., standard deviation; C.V., coefficient of variation; V_{*w}, volume weighted mean proportion; SE, standard error; --, not determined]

Reference station	Dist. (m)	Reach	V_{rf}	V_*	Max D_r (m)	Max D_r D_{rc}	V_r (m^3)	Mean W_r (m)	Pool length (m)	Plan area (m^2)	Mean D_r (cm)
06036950	645	3	1.31	0.337	0.35	0.56	3.89	3.28	18	59.0	5.11
06036950	726	3	4.31	0.091	0.65	1.69	47.3	23.4	25	585	22.4
06037000	104	4	17.99	0.146	1.01	2.03	123	10.1	50	504	24.1
06037000	967	5	1.02	0.068	0.65	1.08	15.0	3.80	20	76.0	20.4
06037000	1058	5	32.25	0.196	0.60	1.50	164	10.7	75	800	21.2
06037000	1903	2	1.70	0.085	0.36	0.71	20.1	6.60	22	145	12.9
06037000	2104	2	3.93	0.262	0.28	0.44	15.0	6.92	35	242	7.24
06037000	2329	2	1.13	0.126	0.32	0.51	8.96	3.62	26	94.1	8.26
06037100	-3798	1	4.64	0.080	0.94	1.49	58.3	6.42	25	161	36.8
06037100	-3354	1	15.92	0.098	0.83	3.32	163	11.2	42	472	35.4
06037100	-3163	1	11.02	0.254	0.62	0.83	43.3	10.8	24	259	17.6
06037100	-2648	0	17.28	0.095	0.78	1.90	183	7.96	65	517	36.8
06037100	-2472	0	6.43	0.254	0.78	1.44	25.3	7.71	19	146	16.0
06037100	-2423	0	16.91	0.291	0.63	1.21	58.2	8.42	30	253	22.9
06037100	-454	6	30.61	0.187	1.29	3.58	163	8.52	45	383	48.1
06037100	-192	6	15.74	0.119	1.00	1.85	132	6.06	41	248	51.6
Mean			65.07	0.168	0.694	1.51	76.5	8.47	35.1	309	24.2
Std. Dev.			--	--	0.283	0.916	65.8	4.70	16.9	213	14.0
C.V. (percent)			--	--	40.9	60.7	86.1	55.6	48.1	69.0	57.8

V_{*w} weighted mean 0.149 (14.9 percent of residual pool volume occupied by fine sediment)

SE 0.017

Table 7. *Particle-size distribution of fine bed sediment in pools, Gibbon River, October 2000*

[Dist., distance from reference station (positive values indicate a downstream position; negative values indicate an usptream position); m, meter; mm, millimeter; µm, micrometer; QC, quality-control replicate sample]

Reference station	Dist. (m)	Reach	Date sampled	Percentage finer than indicated sieve size									
				51 mm	25 mm	12.5 mm	4.75 mm	2.36 mm	1.18 mm	600 µm	300 µm	150 µm	75 µm
06036950	645	3	10-14-00	100	100	99	95	82	52	26	8	3	1.0
06036950	726	3	10-14-00	100	100	98	94	74	53	38	22	5	1.0
06037000	104	4	10-14-00	100	100	100	98	80	43	11	2	1	0.2
06037000	967	5	10-15-00	100	100	98	89	56	20	6	2	0	0.1
06037000	1058	5	10-15-00	100	100	100	97	91	77	57	35	14	4.0
06037000	1058	5	10-15-00	100	100	100	98	87	67	32	9	3	1.0
06037000	1903	2	10-13-00	100	90	86	60	41	27	15	6	2	0.4
06037000	2104	2	10-13-00	100	97	88	73	62	51	30	9	2	0.5
06037000	2104	2	10-15-00	100	97	91	71	50	35	18	4	1	0.2
06037000	2329	2	10-13-00	100	100	97	82	53	30	15	6	2	0.6
06037100	-3798	1	10-13-00	100	100	93	76	68	64	56	29	6	2.0
06037100	-3354	1	10-13-00	100	100	99	95	82	66	38	15	4	1.0
06037100	-3163	1	10-13-00	100	100	100	87	70	63	51	18	4	1.0
06037100	-2648	0	10-12-00	100	100	87	82	66	43	27	12	3	1.0
06037100	-2472	0	10-12-00	100	88	69	55	44	33	18	4	1	0.4
06037100	-2423	0	10-12-00	100	100	99	89	69	46	17	6	2	0.7
06037100	-454	6	10-11-00	100	100	99	93	78	59	28	7	1	0.5
06037100	-192	6	10-11-00	100	100	99	88	70	49	16	2	1	0.5

Table 8. *Particle-size distribution of surficial bed material in a riffle, Gibbon River, October 2000*

[Numbers in **bold** represent the visually estimated embeddedness of individual particles. Dist., downstream distance from reference station; m, meter; n, total number of particles in sample; mm, millimeter]

Station	Dist. (m)	Riffle	Date sampled	n	2	2.8	4	5.6	8	11.2	16	22.6	32	45	64	90	128	180	256	360	512	Mean
						Percentage finer than indicated particle size (mm)																
06037000	2159	D1.5	10-15-00	101	1.0	1.0	3.0	7.9	7.9	12.9	14.9	17.8	20.8	24.8	37.6	55.4	71.3	84.2	92.1	99.0	100.0	
						Estimated percent embeddedness of particle of indicated size (mm)																
Mean for size and class										50	65	55	50	37	44	38	45	48				44
Number of particles				47						1	2	2	2	3	10	12	11	4				
										50	**30**	**60**	**50**	**10**	**10**	**40**	**30**	**40**				
											100	**50**	**50**	**60**	**50**	**60**	**90**	**30**				
														40	**90**	**0**	**70**	**40**				
															10	**80**	**80**	**80**				
															60	**0**	**50**					
															40	**20**	**10**					
															30	**30**	**20**					
															60	**20**	**40**					
															40	**30**	**30**					
															50	**80**	**50**					
																50	**20**					
																40						